THESIS

THE EFFECTS OF AVIAN POX ON PLUMAGE COLORATION IN MALE HOUSE FINCHES (*Carpodacus mexicanus)*

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY LORI R. SPEARS ENTITLED "THE EFFECTS OF AVIAN POX ON PLUMAGE COLORATION IN MALE HOUSE FINCHES (*Carpodacus mexicanus*)" BE ACCEPTED AS FULFILLING PARTIAL REQUIREMENTS FOR THE THESIS IN ZOOLOGY.

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Abstract

Models of sexual selection emphasize that variations in sexual ornamentations have important fitness consequences. For example, males with low parasite loads are thought to be more capable of producing more substantial ornamentations than males with high loads. Consequently, males with high parasite loads are unable to allocate sufficient energy to sexual displays relative to uninfected males and thus are not chosen by females. One ornamental trait likely to be affected by parasitic infections is carotenoid-based plumage coloration. I investigated whether plumage coloration in male House Finches (*Carpodacus mexicanus*) is affected by the presence of avian pox, a viral infection characterized by wartlike lesions. The hue, intensity, and tone of male plumage coloration was quantified. In addition, I also compared the body mass, the length of the longest rectrice, the length of the longest primary, the bill length, and fat measures of infected versus uninfected birds. A total of 175 birds was captured at four sites in northern Utah. Of those captured, 20% had pox-like symptoms. Infected birds were significantly lighter than uninfected birds. Infected birds were also caught more frequently at an urban residential setting than at rural areas. Results indicate that infected males had significantly lower plumage scores and a significantly lower body mass relative to the uninfected males.

Introduction

Variation in secondary sexual characteristics, or exaggerated versions of morphological attributes, can have important fitness consequences. Several studies have demonstrated that females prefer males with elaborate secondary sexual characteristics over males that do not have such intricate ornamentations (Hill et al. 1999, Kose and Møller 1999, Møller 1988). For example, in male Barn Swallows (*Hirundo rustica*) the length of the tail increases the probability of obtaining a mate (Møller 1988).

The House Finch (*Carpodacus mexicanus*) is sexually dichromatic with respect to its plumage coloration (Hill 1993). Females typically are gray-brown while males vary from pale yellow to bright red. The plumage coloration of males are found on the crown, throat, chest, rump and along the side of the eye (Hill 1993). Variation in male plumage coloration is found in all populations and has been shown to affect fitness. Hill et al. (1999) demonstrated that males with bright red coloration were more likely to pair with females relative to pale yellow males. Furthermore, variation in coloration may also affect foraging proficiency and social dominance (Belthoff et al. 1994, Hill 1991).

If females prefer males with a bright red plumage, then how can this variation be maintained? One explanation is the Hamilton-Zuk hypothesis. This hypothesis suggests that females prefer mates that display specific secondary sexual characteristics that indicate the male's quality and that reflect genetically influenced degrees of resistance to disease. For example, males that have low parasite loads are believed to be more capable of producing costlier sexual ornamentations than males with high parasite loads (Hamilton and Zuk 1982). For this reason, infected males are unable to allocate sufficient energy to sexual displays relative

to normal, uninfected males and thus are not chosen as frequently by the females.

One ornamental trait that seems to be affected by parasitic infections and that has received recent attention is the carotenoid-based plumage coloration of the House Finch (Hill 1993, Hill et al. 1999). Carotenoids must be obtained from the environment for the production of red pigments found in males. In captive and wild studies, males produce a dull colored plumage when fed a diet deficient in carotenoids (Hill 1992, Zahn and Rothstein 1999). However, variation in male plumage coloration may also reflect an individual's ability to alter and physiologically process carotenoids (Thompson et al. 1997). For example, several recent studies have examined the effect of parasitic infections on male plumage coloration. These studies suggest that the presence of infections, such as the pathogen *Mycoplasma gallisepticum*, mite infestations, coccidial infections, and avian pox, are negatively correlated with plumage coloration in male House Finches (Brawner et al. 2000, Nolan et al. 1998, Thompson et al. 1997, Zahn and Rothstein 1999). Parasites are thought to interfere with the physiological mechanisms involved in the processing of carotenoids such as the absorption, transport, and metabolism of ingested pigments (Brawner et al. 2000, Thompson et al. 1997).

Thus, the aim of this study was to investigate the prevalence of avian pox in a northern Utah population of *C. mexicanus* and examine the effects of pox infections on plumage coloration in males. The prevalence of avian pox and the effects of pox lesions on *C. mexicanus* in northern Utah had not been examined prior to this study.

Methods

Species and Disease

Historically, House Finches were found from the Pacific coast to eastern Colorado and from the U.S.-Canadian border into southern Mexico (Hill 1993). However, in the 1940s, a small population was introduced to the eastern U.S. This eastern population has since grown exponentially and has expanded its range west. Currently, House Finches cover most of the United States and southern Canada and can be found in a wide range of habitats, including urban areas, grasslands, open coniferous forests, oak savannahs, and deserts. House Finches are gregarious birds and generally travel between food sources in winter. Flock sizes can range from a few to hundreds of birds. They are semi-colonial but socially monogamous, with female mate choice playing an important role in pair formation (Hill 1993). Pair formation occurs between January and March while the birds are still assembled in winter flocks.

Avian pox is a virus characterized by wartlike nodules on featherless surfaces such as the legs, feet, eyelids and mandibles (Hansen 1999). The resulting tumors may cause difficulties in breathing and feeding, loss of toes, occluded vision, and increased susceptibility to secondary infections because of the risk of abrasion. Consequently, pox infections are occasionally lethal. These infections have been reported in many groups of birds such as raptors, galliforms, and passerines (Hansen 1999). The first reported case of House Finches infected with avian pox occurred in 1961 in Hawaii. The disease spread to Californian populations by 1972 and has subsequently spread throughout several western states (Power and Hunman 1976, Warner 1969). There are no published accounts of avian pox disease in eastern populations of House Finches. Avian pox is transmitted by mosquitos, by air-borne particles, and through contaminated surfaces

such as shared feeders and perches (Hansen 1999, Karstad 1971). Birds can be infected year-round but disease outbreaks are more common when environmental conditions favor vector populations in summer and early fall. Because avian pox can also survive on contaminated surfaces, transmission can occur during anytime of the year so long as environmental factors permit virus survival outside of the host (Hansen 1999).

Study Sites

Four sites in northern Utah were monitored. All four sites were located in Weber County. Three of the sites were in Ogden, UT and included the campus of Weber State University, a residential setting 5 blocks west of campus, and a site at the Ogden Nature Center. The remaining site was at a rural setting in Hooper, UT.

Field Methods

House Finches were captured weekly from November 2000 until April 2001 at feeders using mist nets. All birds captured were fitted with a U.S. Fish and Wildlife Service leg band, sexed according to plumage characteristics, and examined for evidence of pox lesions. Viral infections may affect the growth of feathers during the pre-basic molt (Thompson et al. 1997). Consequently, I assessed the effects of pox on feather growth by measuring the length of the longest primary and the length of longest rectrice. I also recorded bill length to assess whether avian pox has an effect on this characteristic as well.

Physical condition was assessed by body mass and fat scores. Birds were weighed to the nearest 0.1 gram on a portable electronic balance. Fat scores were characterized by visually estimating the deposition of fat in the furcular hollow, wing pits, and on the abdomen. Fat scores were assigned 0 if no fat was present in the furcular hollow, 1 if there was <5% fat in the furcular

hollow, 2 if there was 5-33% fat present, 3 if the furcular hollow was about half full, and 4 if the furcular hollow was full and fat was thick in the wing pits and on the abdomen.

Plumage coloration was scored by using the *Methuen Handbook of Colour* which quantifies colors according to hue, intensity, and tone (Kornerup and Wanscher 1983). Hue is defined as the element of a color which determines its name in common usage. Intensity is the brightness of a color and tone quantifies the amount of black present. These three variables are expressed numerically for each color sample represented. The three numbers were combined to arrive at a single digit for each color chip (Fig. 1). The plumage coloration of each male was scored by comparing five pigmented regions to the charted samples. These regions include the crown, eye stripe, throat, chest, and rump. Plumage scores from all five pigmented regions were added together for a total plumage score and averaged to arrive at an average score. The average plumage score of each male captured was then broken down into the following color categories: red/red-orange and orange-yellow/yellow. If the average score was from 16-20, the bird was assigned to the red/red-orange category and if the average score was from 12-16, the bird was assigned to the orange-yellow/yellow category. Because male House Finches vary in color from pale yellow to bright red, pigmented males could not score below 12.

Data Analyses.

All statistical analyses were performed using SPSS software (SPSS 1999). Data were first analyzed to determine if differences existed between sexes in length of longest rectrice, bill length, length of longest primary, fat scores, and body mass. If there was no evidence for sexual dimorphism, then data from both sexes were pooled for remaining analyses. If evidence existed for sexual dimorphism then subsequent analyses were performed separately for each sex.

Analysis of variance (ANOVA) was used to detect differences in body mass, length of longest rectrice, length of longest primary, bill length and fat scores between infected birds and uninfected birds. To determine if there was a difference in disease prevalence between the sexes and among the four sites, a goodness of fit G-test with William's corrections was performed (Sokal and Rohlf 1981). If differences existed between the four sites, a bonferroni correction for multiple comparisons was used in follow up tests to determine where the differences occurred (Sokal and Rohlf 1981). Values reported are means (±SE).

Results

A total of 175 birds was captured: 104 males and 71 females. Of this total, 35 birds (=20%) had pox-like symptoms (Fig. 2). Pox-like symptoms included missing toes and lesions that occurred on the toes, bill, near the eye and at the bend of the wing. The prevalence of avian pox was 23% for males and 16% for females. There was no significant difference between the sexes with respect to disease prevalence ($G = 1.53$, df = 1, $P = >0.05$).

The percentage of infected birds caught at each site are as follows: 35% of birds captured at the residential setting in Ogden (N = 55), 17% of birds captured at campus (N = 58), 9% of birds at the Ogden Nature Center (N = 32), and 10% of birds captured in Hooper (N = 30). The differences between these sites are significant ($G = 11.05$, df = 3, $P = <0.01$). Follow up tests indicate that the residential setting in Ogden harbored significantly more infected birds than did the Ogden Nature Center and the Hooper site (Fig. 3).

There was a significant difference between the length of the longest primary and the length of the tail by sex (Table 1). The average length of the longest primary in males was 78.45

(± 0.23) mm, whereas the average in females was 75.61 (± 0.26) mm. The average tail length of males was 60.59 (± 0.32) mm and the average tail length of females was 58.55 (± 0.42) mm. Hence, males and females were analyzed separately when comparing the length of the tail and the length of the longest primary of infected birds to uninfected birds. There was no significant difference between the sexes with respect to fat scores, body mass, and length of the bill (Table 1). Consequently, I pooled sexes to test for differences between infected and uninfected birds.

Data reveal that infected birds had a significantly lower body mass than birds not infected with pox (Table 2). The average body mass of infected birds was 20.75 (± 0.31) grams, whereas the average body mass of uninfected birds was 21.36 (± 0.13) grams. However, there were no significant differences between infected and uninfected birds with respect to the length of the longest primary, tail length, bill length, and fat scores (Table 2).

The percentage of red/red-orange males in the entire population was 55%, whereas the percentage of orange-yellow/yellow males in the entire population was 45%. Only one bird scored above 18. Infected birds were found to have a duller or yellower plumage than uninfected birds. The total plumage score of infected birds was 74.63 (± 2.15) and 79.67 (± 0.98) for uninfected birds. The average plumage score of infected birds was 14.93 (± 0.43) and 15.94 (± 0.20) for uninfected birds. The differences in male plumage coloration between infected and uninfected birds were statistically significant (Table 2).

Discussion

This study demonstrates that avian pox is prevalent in northern Utah. I found that 20% of birds captured had symptoms of pox lesions with 23% of males and 16% of females showing

symptoms. Similarly, 20% of 78 post-1960 museum specimens collected in southern California had symptoms associated with avian pox (Zahn and Rothstein 1999).

There was a significant difference in the number of birds captured at each site. A possible explanation for this finding is the locality of each site. The Ogden Nature Center and the residential setting in Hooper are rural settings, whereas the other two sites are more urban. Residential sites are likely to contain more bird feeders than rural sites. Bird feeders are believed to help to facilitate transmission of diseases such as avian pox (Hansen 1999). Thus, infected birds may be more prevalent among urban sites because of the ease of transmission offered by bird feeders. Similar to these findings, McClure (1989) found that diseased birds in Ventura County, California were caught more frequently at urban sites where bird feeders were abundant than at rural sites with a lower density of bird feeders.

I also found that infected birds weighed significantly less than uninfected birds. Although the difference in body mass between the two groups was significant, this difference may not be biologically significant because there was only a 2% difference in body mass between the two groups. Nolan et al. (1998) demonstrated that, following an outbreak of *Mycoplasma gallisepticum*, male and female House Finches in Alabama weighed significantly less than before the outbreak occurred. Thus far, no studies have detected a difference in body mass between birds infected with avian pox and birds not infected. Therefore, it is important that further studies examining the effects of avian pox on House Finches monitor this variable over the years.

In this study, there were no significant differences between infected and uninfected birds with respect to the length of the longest primary, tail length, bill length, or fat scores. However, all of these variables, with the exception of fat scores, have been shown to be affected by

parasitic infections in other studies. For example, Thompson et al. (1997) found that the wing length of House Finches infected with mites in California was significantly reduced compared to House Finches that were not infected with mites. Similarly, Nolan et al. (1998) found that wing length and bill length decreased significantly when a House Finch population in Alabama became exposed to *Mycoplasma gallisepticum*. However, Nolan et al. (1998) also found that the tail length of males increased significantly following this outbreak. Although this study does not record any significant differences between infected and uninfected birds, a general trend does exist. The average wing length and bill length of infected birds is slightly shorter than that of uninfected birds. No previous studies have detected or examined a difference in fat scores of infected birds and uninfected birds.

This study has shown that avian pox is significantly correlated with the reduced expression of male plumage coloration. This suggests that male plumage coloration may signal physical condition because the pigmentation of birds with pox-like symptoms was significantly yellower than that of birds without the disease. Studies examining effects of parasitic infections on ornamental traits have found that infected birds are unable to display the decorative sexual traits their healthy counterparts exhibit (Brawner et al. 2000, Nolan et al. 1998, Thompson et al. 1997, Zahn and Rothstein 1999). For example, Thompson et al. (1997) found that male House Finches with high mite loads and avian pox were incapable of producing bright plumage. Similarly, Nolan et al. (1998) report that bright males were more likely to survive an epidemic than dull males. Following an outbreak of *Mycoplasma gallisepticum*, bright red males were caught significantly more than drab males.

I also found that 55% of the entire male population captured were red/red-orange,

whereas 45% of the entire male population captured were orange-yellow/yellow. Interestingly, in areas where pox has not been reported, 95.3% of males were red (W. Wehtje unpublished data *cited in* Zahn and Rothstein 1999). These findings further support the idea that avian pox has a dramatic effect on male plumage coloration.

Bright plumage coloration has also been correlated with nest attentiveness. Hill (1991) reports that bright red males invested in parental behaviors more often than males that were drab in color. Bright males fed their mates and their offspring more frequently than dull colored males. Moreover, females will often abandon their nests if the provisioning by males is inadequate. Hill (1991) found that bright males were seldom deserted compared to dull colored males.

The metabolic processes involved in the conversion of carotenoid pigments to plumage coloration are considered to be interrupted when parasites are present (Brawner et al. 2000, Thompson et al. 1997). It has been suggested that parasitic infections dampen the expression of carotenoid pigments by disrupting the physiological processes that are involved in producing plumage coloration. However, the exact mechanism is unknown. Therefore, although birds are able to physiologically convert yellow pigments to red pigments, the quality and quantity of ingested pigments becomes especially irrelevant when the bird is parasitized. Furthermore, pathogens are also known to attack specific sites involved with the absorption of particular carotenoids (Zahn and Rothstein 1999). Thus, it is possible that avian pox attacks the site specific to the conversion of ingested red carotenoids to feather pigmentation.

Conclusions

The results presented in this study demonstrate that a relationship exists between parasitism and plumage coloration of male House Finches. Thus, females choosing brightly colored males are choosing mates that are in good physiological condition. It is possible that avian pox has a detrimental effect on fitness in male House Finches and could possibly have a major influence on the entire population as well. For example, the presence of avian pox may have an effect on mate selection, parental care, and nestling and fledgling survival. Although infected birds may have some level of reproductive success, avian pox may also have an effect on the reproductive success of individuals. Therefore, future research should strive to elucidate the effects of avian pox on the survival rates and various other population and behavioral characteristics of House Finches.

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Table 1. Statistical results of differences between male and female House Finches.

		F	df	P
TAIL LENGTH	Between groups Within Groups Total	15.38	1 139 140	0.000*
WING LENGTH	Between groups Within Groups Total	66.20	1 170 171	0.000*
FAT SCORE	Between groups Within Groups Total	0.06	1 146 147	0.809
BODY MASS (g)	Between groups Within Groups Total	0.75	1 164 165	0.389
BILL LENGTH	Between groups Within Groups Total	0.42	1 140 141	0.520

*Statistically significant (ANOVA).

Table 2. Statistical results of differences between infected and uninfected House Finches.

		Mean infected	Mean Uninfected	F	df	P
FAT SCORE	Between Groups Within Groups Total	2.38	2.20	1.031	1 146 147	0.312
BODY MASS (g)	Between Groups Within Groups Total	20.75 g	21.36 g	4.221	1 164 165	0.042*
BILL LENGTH	Between Groups Within Groups Total	8.88 mm	8.98 mm	0.387	1 140 141	0.535
TOTAL PLUM.	Between Groups Within Groups Total	74.63	79.67	4.213	1 49 50	0.045*
AVG PLUM.	Between Groups Within Groups Total	14.93	15.94	4.213	1 49 50	0.045*
WING (MALE)	Between Groups Within Groups Total	77.88 mm	78.63 mm	2.030	1 100 101	0.157
WING (FEMALE)	Between Groups Within Groups Total	74.80 mm	75.75 mm	1.609	1 68 69	0.209
TAIL (MALE)	Between Groups Within Groups Total	60.40 mm	60.63 mm	0.075	1 81 82	0.784
TAIL (FEMALE)	Between Groups Within Groups Total	59.75 mm	58.36 mm	1.344	1 56 57	0.251

*Statistically significant (ANOVA).

Figure 1. A representation of how plumage coloration was scored (Photograph courtesy of Chipper Woods Bird Observatory, Inc.). The bird was compared to charted samples. A score was then assigned to each of the five pigmented regions.

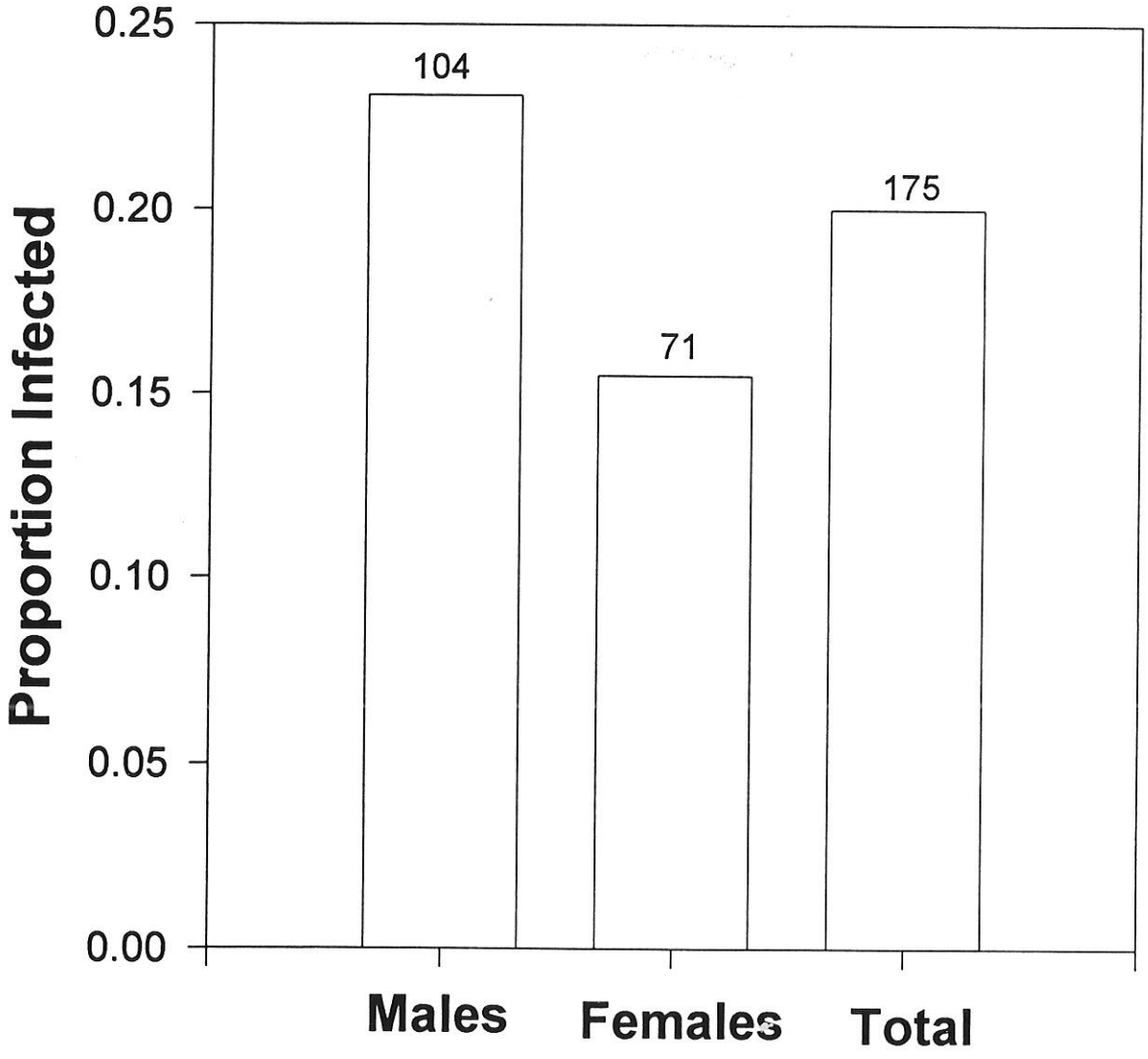

Figure 2. Prevalence of avian pox among House Finches in northern Utah. Sample sizes are represented above the bars.

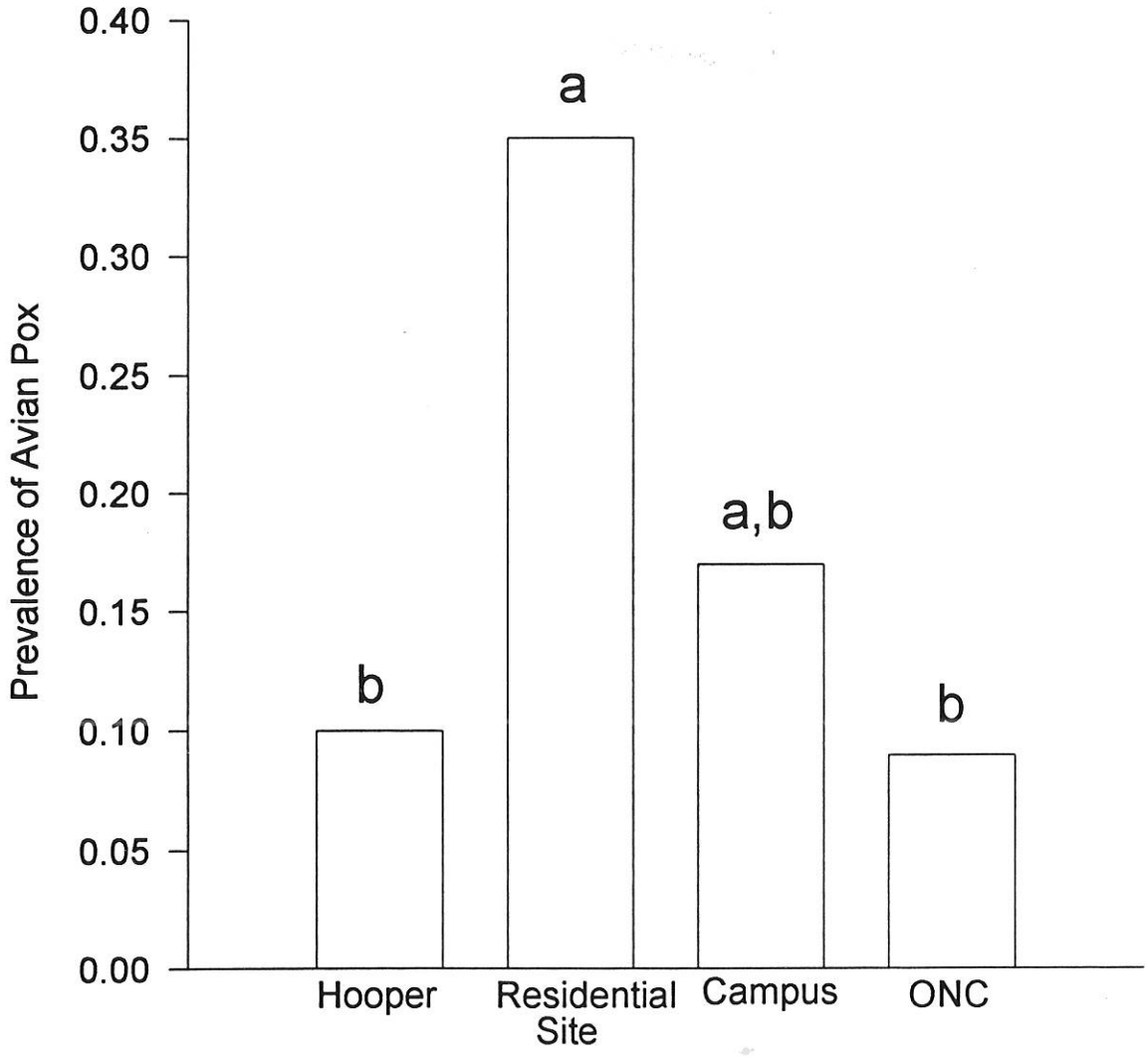

Figure 3. Prevalence of avian pox at each of the four sites. Values with the same letter are not significantly different (Hooper vs. Residential site, $G_{adj}=6.62$, $P<0.01$; Hooper vs. Campus, $G_{adj}=0.83$, $P>0.05$; Hooper vs. ONC, $G_{adj}=0.006$, $P>0.05$; Residential site vs. Campus, $G_{adj}=4.40$, $P\leq0.05$; Residential vs. ONC, $G_{adj}=7.37$, $P<0.01$; Campus vs. ONC, $G_{adj}=1.05$, $P>0.05$).